

1 What is claimed is:

2 1. A method for carrier tracking and spread spectrum code
3 tracking in a spread spectrum communication system, the method
4 comprising the steps of,

5 receiving a spread spectrum input signal having inphase
6 and quadrature components communicating a spread spectrum code
7 modulating a carrier,

8 carrier generating quadrature demodulation signals
9 referenced to a local reference, the quadrature demodulation
10 signals having a carrier phase referenced to the carrier,

11 demodulating the spread spectrum input signal by the
12 quadrature demodulation signals for generating the inphase and
13 quadrature components,

14 code generating early and late code replicas of the spread
15 spectrum code, the early and late code replicas having a code
16 phase referenced to the spread spectrum code,

17 correlating the inphase and quadrature components by the
18 early and late code replicas for generating early and late
19 inphase and quadrature correlation signals,

20 residual generating a residual from the early and late
21 inphase and quadrature correlation signals and from a code phase
22 error state and an amplitude state and a carrier phase error
23 state and frequency error state,

24 calculating a code phase error and an amplitude and a
25 carrier phase error and a carrier frequency error from the
26 residual and a state error covariance matrix and the code phase
27 error state and the amplitude state and the carrier phase error
28 state and the frequency error state,

1 propagating the code phase error state and the amplitude
2 state and the carrier phase error state and the carrier
3 frequency error state from the code phase error and the
4 amplitude and the carrier phase error and the carrier frequency
5 error,

6 Riccati estimating the state error covariance matrix from
7 the code phase error state and the amplitude state,

8 carrier phase adjusting the quadrature demodulation
9 signals by the carrier phase error for reducing the carrier
10 phase between the carrier and the quadrature demodulation
11 signals for tracking the carrier, and

12 code phase adjusting the early and late code replicas by
13 the code phase error for reducing the code phase between the
14 spread spectrum code and early and late code replicas for
15 tracking the spread spectrum code.

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18 2. The method of claim 1 wherein,

19 the state error covariance matrix is a Riccati state error
20 covariance matrix P defined by an algebraic Riccati equation of
21 the form $0 = AP + P^T A + W - Ph^T V^{-1} h P$ where A is a state dynamics matrix,
22 V^{-1} is an inverse observation covariance, h is a linearized
23 observation matrix, h^T is a transposed linearized observation
24 matrix, and W is a state covariance.

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27 3. The method of claim 1 wherein the communication system is a
28 GPS receiver and the code phase error is a range error.

1 4. The method of claim 1 wherein,

2 the spread spectrum input signal is a GPS spread spectrum
3 signal,

4 the local reference is a local oscillator for coherent
5 demodulation of the spread spectrum input signal, and

6 the spread spectrum code is a direct sequence spread
7 spectrum code.

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9 5. The method of claim 1 wherein the code phase error state and
10 the amplitude state are assigned constant nominal values during
11 the estimating step.

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14 6. The method of claim 1 further comprising the steps of,

15 transmitter calculating a transmitter position and a
16 transmitter velocity from the spread spectrum input signals,

17 receiver calculating a receiver position and a receiver
18 velocity from the early and late inphase and quadrature
19 correlation signals,

20 range calculating a range and a range rate from the
21 transmitter and receiver positions and velocities, the range
22 rate further adjusting the quadrature demodulation signals for
23 reducing the carrier phase between the carrier and the
24 quadrature demodulation signals for tracking the carrier, the
25 range further adjusting the early and late code replicas for
26 reducing the code phase between the spread spectrum code and
27 early and late code replicas for tracking the spread spectrum
28 code.

1 7. The method of claim 1 wherein,

2 the calculating step further calculates a carrier frequency
3 rate error,

4 the propagating step further propagates a carrier frequency
5 rate error state, and

6 the residual generating step generates the residual from the
7 early and late inphase quadrature correlation signals and from
8 the code phase error state and the amplitude state and the
9 carrier phase error state and the carrier frequency error
10 state.

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12 8. The method of claim 1 wherein the residual generating step
13 and the calculating step and the propagating step and the
14 Riccati estimating step are a Kalman prefiltering process in a
15 spread spectrum receiver in the spread spectrum communication
16 system.

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1 9. A method for carrier tracking and spread spectrum code
2 tracking in a GPS navigation processor in a GPS spread spectrum
3 receiver, the method comprising the steps of,
4 receiving the GPS spread spectrum input signal having
5 inphase and quadrature components communicating a spread
6 spectrum code modulating a carrier,
7 carrier generating quadrature demodulation signals
8 referenced to a local reference, the quadrature demodulation
9 signals having a carrier phase referenced to the carrier,
10 demodulating the GPS spread spectrum input signal by the
11 quadrature demodulation signals for generating the inphase and
12 quadrature components,
13 code generating early and late code replicas of the spread
14 spectrum code, the early and late code replicas having a code
15 phase referenced to the spread spectrum code,
16 correlating the inphase and quadrature components by the
17 early and late code replicas for generating early and late
18 inphase and quadrature correlation signals,
19 residual generating a residual from the early and late
20 inphase and quadrature correlation signals and from a code phase
21 error state and an amplitude state and a carrier phase error
22 state and frequency error state,
23 calculating a code phase error and an amplitude and a
24 carrier phase error and a carrier frequency error from the
25 residual and a state error covariance matrix and the code phase
26 error state and the amplitude state and the carrier phase error
27 state and the frequency error state,
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1 propagating the code phase error state and the amplitude
2 state and the carrier phase error state and the carrier
3 frequency error state from the code phase error and the
4 amplitude and the carrier phase error and the carrier frequency
5 error,

6 Riccati estimating the state error covariance matrix from
7 the code phase error state and the amplitude state,

8 navigation calculating a receiver position and a receiver
9 velocity from the early and late inphase and quadrature
10 correlation signals,

11 satellite calculating a satellite position and a satellite
12 velocity from the GPS spread spectrum input signal,

13 range calculating a pseudorange and a pseudorange rate
14 from the receiver and satellite positions and velocities,

15 carrier phase adjusting the quadrature demodulation
16 signals from the pseudorange rate and by the carrier phase
17 error for reducing the carrier phase between the carrier and
18 the quadrature demodulation signals for tracking the carrier,
19 and

20 code phase adjusting the early and late code replicas from
21 the pseudorange and by the code phase error for reducing the
22 code phase between the spread spectrum code and early and late
23 code replicas for tracking the spread spectrum code.

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1 10. The method of claim 9 wherein,

2 the navigation calculating step further calculates clock
3 error estimates, and

4 the range calculating step calculates the pseudorange and
5 the pseudorange rate from the receiver and satellite positions
6 and velocities and from the clock error estimates.

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8 11. The method of claim 9 wherein the residual generating step
9 and the calculating step and the propagating step and the
10 Riccati estimating step are a Kalman prefiltering process in
11 the GPS spread spectrum receiver.

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13 12. The method of claim 9 wherein,

14 the state error covariance matrix is a Riccati state error
15 covariance matrix P defined by an algebraic Riccati equation of
16 the form $0 = AP + P^T A + W - Ph^T V^{-1} hP$ where A is a state dynamics matrix,
17 V^{-1} is an inverse observation covariance, h is a linearized
18 observation matrix, h^T is a transposed linearized observation
19 matrix, and W is a state covariance.

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1 13. A method for carrier tracking and spread spectrum code
2 tracking in an inertial GPS navigation processor in a GPS
3 spread spectrum receiver receiving inertial measurement
4 samples, the method comprising the steps of,
5 receiving the GPS spread spectrum input signal having
6 inphase and quadrature components communicating a spread
7 spectrum code modulating a carrier,
8 carrier generating quadrature demodulation signals
9 referenced to a local reference, the quadrature demodulation
10 signals having a carrier phase referenced to the carrier,
11 demodulating the GPS spread spectrum input signal by the
12 quadrature demodulation signals for generating the inphase and
13 quadrature components,
14 code generating early and late code replicas of the spread
15 spectrum code, the early and late code replicas having a code
16 phase referenced to the spread spectrum code,
17 correlating the inphase and quadrature components by the
18 early and late code replicas for generating early and late
19 inphase and quadrature correlation signals,
20 residual generating a residual from the early and late
21 inphase an quadrature correlation signals and from a code phase
22 error state and a amplitude state and a carrier phase error
23 state and frequency error state,
24 calculating a code phase error and an amplitude and a
25 carrier phase error and a carrier frequency error from the
26 residual and a state error covariance matrix and the code phase
27 error state and the amplitude state and the carrier phase error
28 state and the frequency error state,

1 propagating the code phase error state and the amplitude
2 state and the carrier phase error state and the carrier
3 frequency error state from the code phase error and the
4 amplitude and the carrier phase error and the carrier frequency
5 error,
6 Riccati estimating the state error covariance matrix from
7 the code phase error state and the amplitude state,
8 integrating the amplitude and the code phase error and the
9 carrier phase error and the carrier frequency error and the
10 state error covariance matrix for providing an error state
11 vector,
12 navigation calculating a receiver position and a receiver
13 velocity from the error state vector and from the inertial
14 measurement samples,
15 satellite calculating a satellite position and a satellite
16 velocity from the GPS spread spectrum input signal,
17 range calculating a pseudorange and a pseudorange rate
18 from the receiver and satellite positions and velocities,
19 carrier phase adjusting the quadrature demodulation
20 signals from the pseudorange rate for reducing the carrier
21 phase between the carrier and the quadrature demodulation
22 signals for tracking the carrier, and
23 code phase adjusting the early and late code replicas from
24 the pseudorange for reducing the code phase between the spread
25 spectrum code and early and late code replicas for tracking the
26 spread spectrum code.
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1 14. The method of claim 13 wherein,

2 the integrating step further provides clock error
3 estimates, and

4 the range calculating step calculates the pseudorange and
5 the pseudorange rate from the receiver and satellite positions
6 and velocities and from the clock error estimates.

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8 15. The method of claim 13 wherein the residual generating step
9 and the calculating step and the propagating step and the
10 Riccati estimating step are a Kalman prefiltering process in
11 the GPS spread spectrum receiver.

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13 16. The method of claim 13 wherein,

14 the state error covariance matrix is a Riccati state error
15 covariance matrix P defined by an algebraic Riccati equation of
16 the form $0 = AP + P^T A + W - Ph^T V^{-1} hP$ where A is a state dynamics matrix,
17 V^{-1} is an inverse observation covariance, h is a linearized
18 observation matrix, h^T is a transposed linearized observation
19 matrix, and W is a state covariance.

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